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Design and Analysis of Triple Band Miniaturized Antenna for Wearable Application

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ABSTRACT: Use of miniaturized antenna for advance wireless communication is trending since last couple of decades. Wearable applications, such as smart watches are using WiFi (Wireless Fidelity), Bluetooth, or BLE (Bluetooth Low Energy) as the way of communication technology. These communication technologies are operating at a commonly used ISM frequency band, 2.4GHz. This frequency band is unlicensed and free to use. In this article, designed MIMO antenna can be used at 2.37GHz, 3.94GHz and 5.96GHz frequencies. This antenna is designed by using multiple slots on single patch, separated by calculated distances. Improvement in VSWR, Directivity and Gain can be achieved by using microstrip patch antenna. Return loss of Designed MIMO is below -10dB and VSWR is in between 1 to 2 at 2.37GHz, 3.94GHz and 5.96GHz.

KEYWORDS: Microstrip Patch Antenna, Patch, Wearable Applications'.

I. INTRODUCTION

Microstrip Patch antennas have several advantages over conventional antenna and therefore are used in a variety of practical applications.

They have been widely used for the applications such as RFID, broadcast radio, mobile systems, GPS, TV, MIMO, vehicle collision avoidance system, satellite communications, surveillance systems, direction founding, RADAR systems, remote sensing, missile guidance, and so on.

It improves the directivity, Gain and Antenna efficiency since it does not require additional transmit power. To maintain VSWR in between 1:2, the approximate value of impedance of a transmission line, must equals the approximate value of the impedance of a transmitter antenna, or vice versa, it is termed as Impedance matching. Impedance matching is necessary between the antenna and the circuitry. The impedance of the antenna, the transmission line, and the circuitry should match so that maximum power transfer takes place between the antenna and the receiver or the transmitter.

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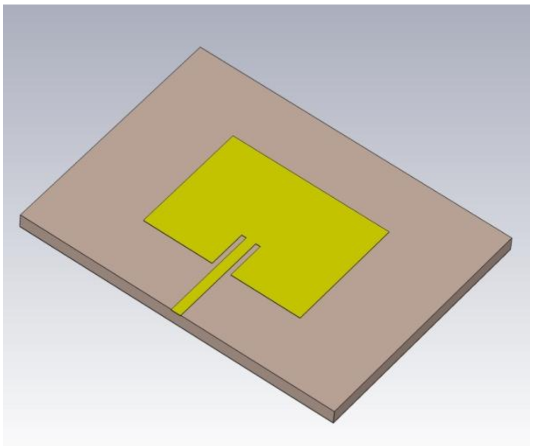

Fig. 1: General Structure of Microstrip Antenna.

If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power will not be radiated effectively. Instead, some of the power is reflected back in the form of reflected/standing waves. The term, which indicates the impedance mismatch, is VSWR. VSWR stands for Voltage Standing Wave Ratio. It is also called as SWR. The higher the impedance mismatch, the higher will be the value of VSWR.

II. REVIEW OF LITERATURE

Snehal Surwase et. al. [1], The 4 element Multiple Input Multiple output (MIMO) Microstrip Patch Antenna that has 4 ports, been designed and implemented in [28], The proposed antenna consists of four ports with all the four patches operates at LTE and WLAN frequencies 1.8GHz, 2.8GHz, 3.3 GHz. The antenna is fabricated on an inexpensive FR4 material of a dielectric constant of $\varepsilon = 4.4$, with thickness of substrate that is 1.6 mm and the thickness of patch is 0.035 mm.

From practical results of Dhanashree Yadav et. al. [2], it is concluded that the increase in the number of patches on the substrate, data rate and radiation pattern get increased. The Proposed design is of 3 bands which is resonating at three frequencies and that are 1.8GHz, 2.8GHz and 3.3GHz and it gives VSWR in the range of 1 to 2 and the values of S Parameters which are less than -10 dB.

Kartiki Gaikwad et. al. [3], demonstrated, two element slotted patch antenna for two different applications that is Wi-Fi (wireless fidelity) and LTE (long term evolution) which operates on the frequency 2.4GHz and 2.6GHz.

Ashish A. Jadhav et. al. [4], Comparison of various methodologies of antenna design and different software tools used for simulation is done to propose powerful techniques to proceed in the field of Microstrip Patch Antenna design for implementation of MIMO systems. Antenna system with high data rate, high gain, wider bandwidth, improved signal quality, higher spectral efficiency, reduced mutual coupling, low cost and small size is the need of today's wireless communication engineering. Hence, overall objectives of this article is to summarize and study different shapes of MIMO antennas and compare different parameters of various designs of antenna such as Mutual coupling, Resonating Frequency, VSWR, Bandwidth, Data rate, Efficiency, Gain and Return Loss.

MIMO antenna systems will also be used for next generation wireless terminals, i.e. 5G and beyond. For every new wireless generation the data rates and channel capacities are growing. Hence, a very large leap is expected by the year 2020 where data rates in the ranges of tens of gigabits per second are expected from mobile terminals and other compact devices. In this paper, a novel compact two element MIMO array is developed resonating at 5.4 GHz with a reduced mutual coupling of –31 dB. These characteristics are well suitable for applications, using which high data rates can be obtained. We can further improve the channel capacity by employing more number of antennas in the system [5].

A good design of antenna can improve the performance of the system. In [6], authors have proposed an inverted U-shaped patch antenna which produces dual band of frequencies resonates at 2.8GHz and 6.4GHz with

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excellent return loss of <-25dB. Hence from the results it is concluded that this antenna is well suited for wireless(WLAN) and satellite communications.

Design Steps:

1	Resonating Frequency	$F_r =$	2.4	$x10^{9}$	Hz
2	Permittivity	$\varepsilon_r =$	4.4		
3	Speed of Light	C =	3	$x10^{8}$	m/s
4	Substrate Height	h =	1.6	$x10^{-3}$	m
5	Calculation of W (Width of Patch 2)	W =	$\frac{C}{2Fr\sqrt{(\varepsilon_r+1)/2}}$		
		W =	12.38		mm
6	Calculation of ε_{reff}	$\varepsilon_{reff} =$	40.84		
7	Calculation of L (Length of Patch 2)	$L_{eff} =$	$\frac{C}{2Fr\sqrt{\varepsilon_{reff}}}$		
		$L_{eff} =$	9.78		mm
	and	$\Delta L =$	0.412 x h	$\frac{(\varepsilon_{reff} + 0.3)(W/h + 0.264)}{(\varepsilon_{reff} - 0.258)(W/h + 0.8)}$	
		$\Delta L =$	0.63	mm	
		L =	Leff - 2 ΔL		
		L =	8.53	mm	
8	Calculation of Lg (Length of Ground)	Lg =	2 x L		
		Lg =	23.13	mm	
9	Calculation of Wg (Width of Ground)	Wg =	2 x W		
		Wg =	33.00	mm	
10	Calculation of Fi (Length of Fed Line)	Fi =	$\frac{6\,h}{2}$		
		Fi =	4.8	Mm	
11	The Gap between the patch and the inset feed (Gpf) is usually 1mm	Gpf =	1	mm	

From above example, for resonating at 2.37GHz, 3.94GHz and 5.96GHz frequencies, dimensions of Patch are decided as shown in Table-1.

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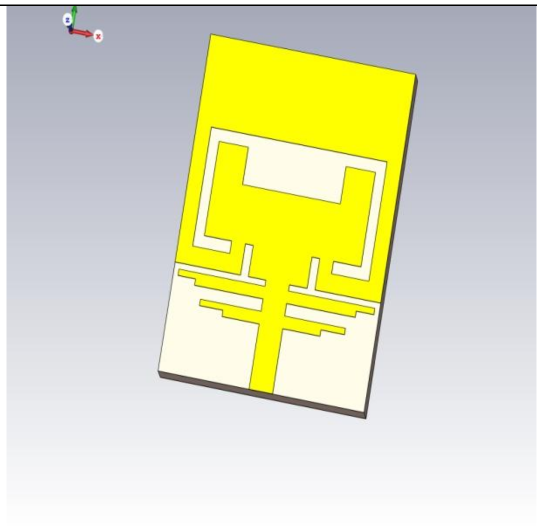
Table-1: Dimensions of Microstrip Patch

Sr. No.	Dimension	Length (mm)
1	Width of Ground Plane	19
2	Length of Ground Plane	4.5
3	Thickness of Ground Plane	0.035
4	Width of Substrate	19
5	Length of Substrate	27
6	Thickness of Substrate	1.6
7	Width of Patch	19
9	Length of Patch	18.3
10	Thickness of Patch	0.035
11	Width of feedline	3.08
12	Length of feedline	5.2



Other dimensions of the Microstrip patch are mentioned in Fig.2.

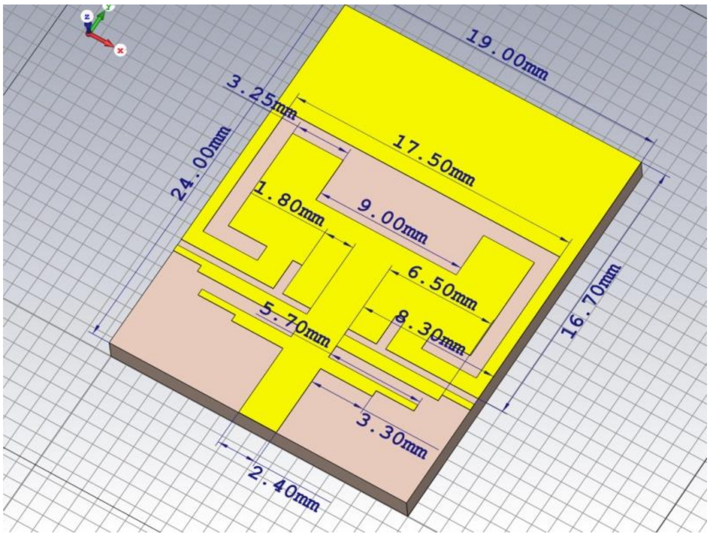


Fig. 2: Triple Band Miniaturized Antenna Patch resonating at 2.37GHz, 3.94GHz and 5.96GHz frequencies.

The Proposed design is of 3 bands which is resonating at three frequencies and that are 2.37GHz, 3.94GHz and 5.96GHz frequencies, and it gives VSWR in the range of 1 to 2 and the values of S Parameters which are less than -10 dB.

One Microstrip patch is used to resonate at selected bands of frequencies. FR4 material is used as dielectric substrate between ground plane and the patches. Dielectric constant of FR4 is 4.4 and thickness of FR4 is 1.6 mm. Ground Plane of Proposed Triple Band Miniaturized Antenna for three different bands of frequencies is shown in figure 3.

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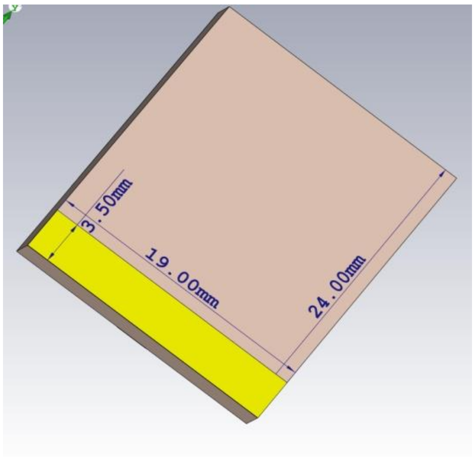

Fig. 3: Triple Band Miniaturized Antenna Ground Plane

III. RESULTS AND DISCUSSIONS

S-Parameter:

Microstrip antenna patch design resonates at 2.37GHz, 3.94GHz and 5.96GHz frequencies. At those three resonating frequencies, values of S-Parameters are -34.99dB, -26.85dB and -19.42dB respectively. Simulation result of 3-Band Triple Band Miniaturized is shown in Fig. 4.

Frequency (GHz)	S- Parameter (dB)
2.37	-34.99
3.94	-26.84
5.96	-19.42

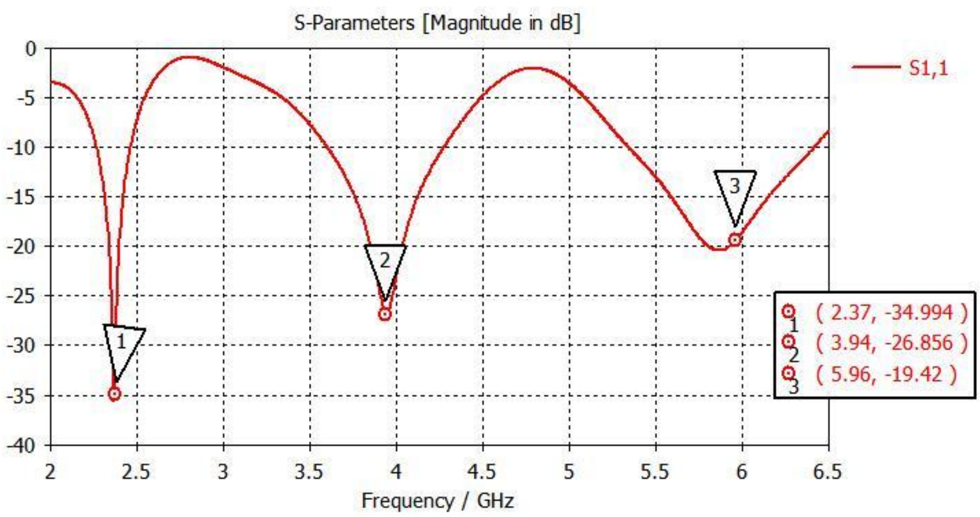

Fig. 4: S- Parameter of Triple Band Miniaturized Antenna

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Bandwidth Enhancement:

Bandwidth of antenna is calculated below -10dB line of S-Parameter plot. The patch resonates at three different frequencies with three wide frequency bands. Microstrip antenna patch design resonates at 2.37GHz (from 2.267 to 2.463 GHz, Bandwidth: 196 MHz), 3.94GHz (from 3.6015 to 4.2751GHz, Bandwidth: 674 MHz) and 5.96GHz (from 5.3336 to 6.4147 GHz, Bandwidth: 1080 MHz) as shown in Fig.5.

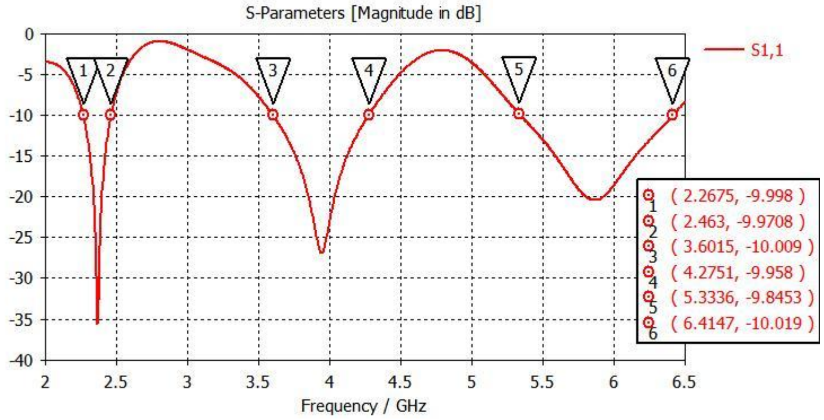

Fig.5. Bandwidth of Triple Band Miniaturized Antenna.

Reference Impedance:

If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power will not be radiated effectively. Instead, some of the power is reflected back in the form of reflected/standing waves.

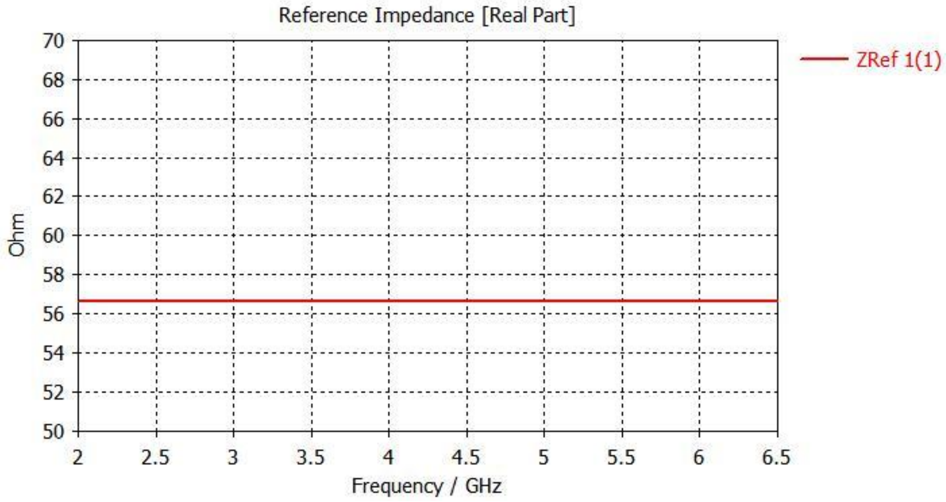

Fig. 6. Reference impedance (Zref) of Triple Band Miniaturized Antenna

To match 50Ω transmission line impedance, Impedance of Patch is made 50Ω by selecting 3.08mm width of feedline. Fig.6. Shows simulated values of reference impedance (Zref) of Triple Band Miniaturized Antenna.

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Voltage Standing Waves Ratio (VSWR):

The ratio of the maximum voltage to the minimum voltage in a standing wave is known as Voltage Standing Wave Ratio. If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power will not be radiated effectively. Instead, some of the power is reflected back in the form of reflected/standing waves. The term, which indicates the impedance mismatch is VSWR. VSWR stands for Voltage Standing Wave Ratio. It is also called as SWR. The higher the impedance mismatch, the higher will be the value of VSWR.

Antenna to resonate efficient must have VSWR value in the range 1-2. The simulated MIMO antenna for six different frequencies is having VSWR between 1 and 2 as shown in Fig. 7.

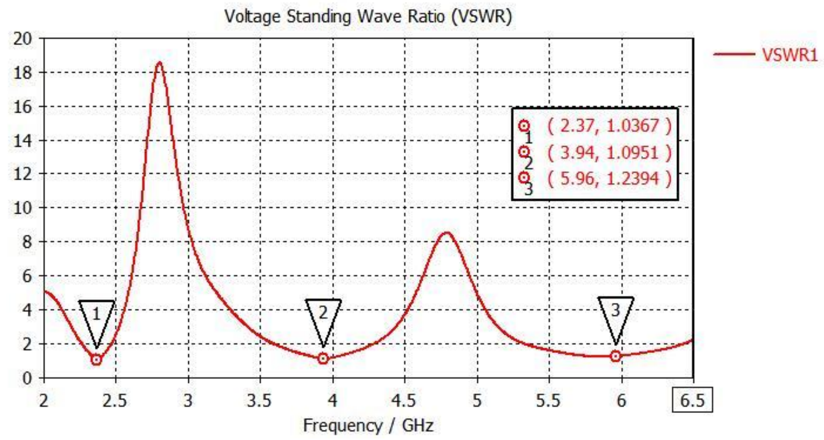

Fig. 7: VSWR of Triple Band Miniaturized Antenna

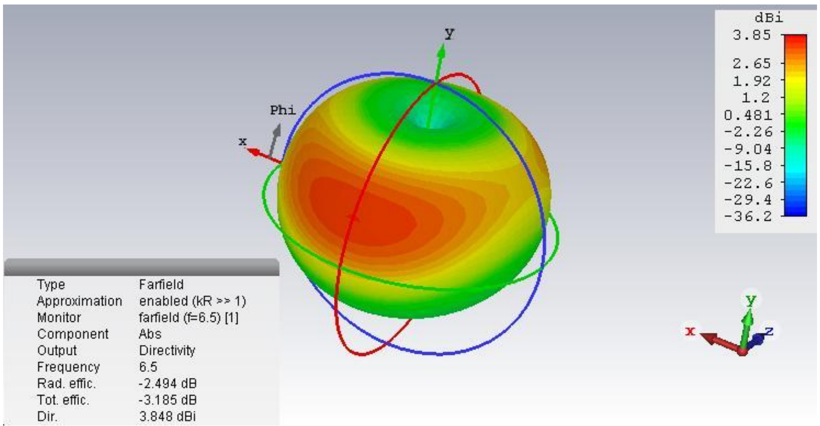

Fig.8 Radiation Pattern of Triple Band Miniaturized Antenna

Fig.8 shows radiation pattern of Triple Band Miniaturized Antenna. At 6.5 GHz frequency, above radiation pattern is observed and total directivity obtained is 3.848dBi

IV. CONCLUSION

Simulation results show that, it is possible to design an Triple Band Miniaturized Antenna to resonate at 3 different frequencies (2.37GHz, 3.94GHz and 5.96GHz frequencies). S- Parameter at those frequencies are less than -10dB and VSWR is between 1 and 2. Average bandwidth obtained at all the 3-Bands of operating frequency is 750 MHz. This

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Triple Band Miniaturized antenna is designed by using multiple slots on single patch, and it can be used in wearable applications.

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